Physics Flash
May 2016
Approved for public release; distribution is unlimited.

INSIDE

Los Alamos NATIONAL LABORATORY EST. 1943

Ray Newell (third from left) meets with members of the media during the recent RSA Conference 2016.

Generating excitement

Los Alamos-developed technology is a hit at international cybersecurity conference

Ray Newell was in the spotlight recently at the largest annual meeting of people and companies working on computer security. The Applied Modern Physics (P-21) researcher (third from left) was at RSA Conference 2016 in San Francisco with representatives from Whitewood Encryption Systems, Inc., to explain the quantum random number generator developed in partnership between Los Alamos and the private company. "The week was a great success; our booth was busy for the entire time–four days!–and quite a few folks told us it was the most interesting thing they'd seen at the conference," Newell said.

Quantum random number generation technology, commercialized by Whitewood under the name Entropy Engine, is a plug-and-play computer card that fits most network servers. It creates truly random numbers at a rate up to 200 million bits each second and can deliver them on-demand over a network to existing encryption applications and devices performing cryptographic operations across datacenters, cloud computing systems, mobile phones and the internet of things. The Entropy Engine produces random bits with the strongest security assurances, and at the highest rates, of any hardware random number generator on the market today.

Los Alamos physicists developed a quantum random number generator to exploit the immutable laws of quantum physics to improve cybersecurity. These physical laws state that events at the subatomic level cannot be predicted; random quantum events lie at the root of the universe. From that starting point, Los Alamos developed a revolutionary method to generate unpredictable, provably unpredictable random numbers.

In 2015, Los Alamos National Laboratory partnered with Whitewood Encryption Systems, Inc., to commercialize the quantum random number generator. The work was initially funded

continued on page 3

"When conditions change, you should rethink the hazard analysis and make the appropriate changes in the planned work."

David

From David's desk . . .

As many of you know, we had a safety "near miss" this year. I am not describing this to blame the team, I want everyone to think about the important lessons learned. The Pharos spectrometer at the Lujan Center is undergoing demolition and disposal (D&D). This is a multi-ton spectrometer that included $7 million of 3He detectors. DOE's Office of Basic Energy Sciences is funding the project. The project plan was to have all of the electrical circuits air-gapped before proceeding with the removal of cables and conduit. It was subsequently found that two of the circuits had not been air-gapped. The team paused work, as it should have. After discussion, the team decided it could work around the non-air-gapped circuits, verifying that the conduits to be cut were empty. Work resumed and, at some point, while cutting empty conduit, a worker inadvertently cut through a conduit that was connected to one of these circuits. Luckily the breaker had been turned off, or I might be writing a different message. But the breaker had not been locked out.

To me, the fundamental lesson learned here is that when the team resumed work, they did not consider the extent to which the hazards had changed. As one person said, an administrative control had replaced an engineering one. There was insufficient reanalysis of hazards in light of this and the IWD was unchanged. Work then proceeded. If there had been a more thorough reanalysis of the hazards, it is likely that the path forward would have been different, and hopefully safer. In summary, I hope all of you will consider the lessons learned here in your work. When conditions change, you should rethink the hazard analysis and make the appropriate changes in the planned work.

On other topics, I said in the last *Physics Flash* that I had met with all of the teams in the Division. I apologize to P-27's Radiation Effects and Radiography team. Somehow, I never managed to schedule a meeting with them. That will be rectified soon.

There continue to be changes in the division's management and in my office. I thank Frank Merrill for agreeing to be P-23 group leader and David Oro for acting so long. I am looking forward to working with Frank. I have two more searches getting started. Chad Olinger will be departing for West Point in June, so we are searching for a P-21 group leader. Congratulations to Gus Sinnis for being appointed LANSCE user facility director and deputy associate director for ADEPS. Aaron Couture has agreed to take the acting P-27 group leader as a search for a "permanent" one is ongoing (Thank you).

Finally, Steve Glick is retiring. I will miss all of the help and support that he gave me during my transition into this role. I wish him the best in retirement. Gerri Barela will be taking Steve's responsibilities within the division office. A search is underway for a new administrator for the office. Until that is completed, Trish Smith will be performing that job.

Physics Division Leader David Meyerhofer

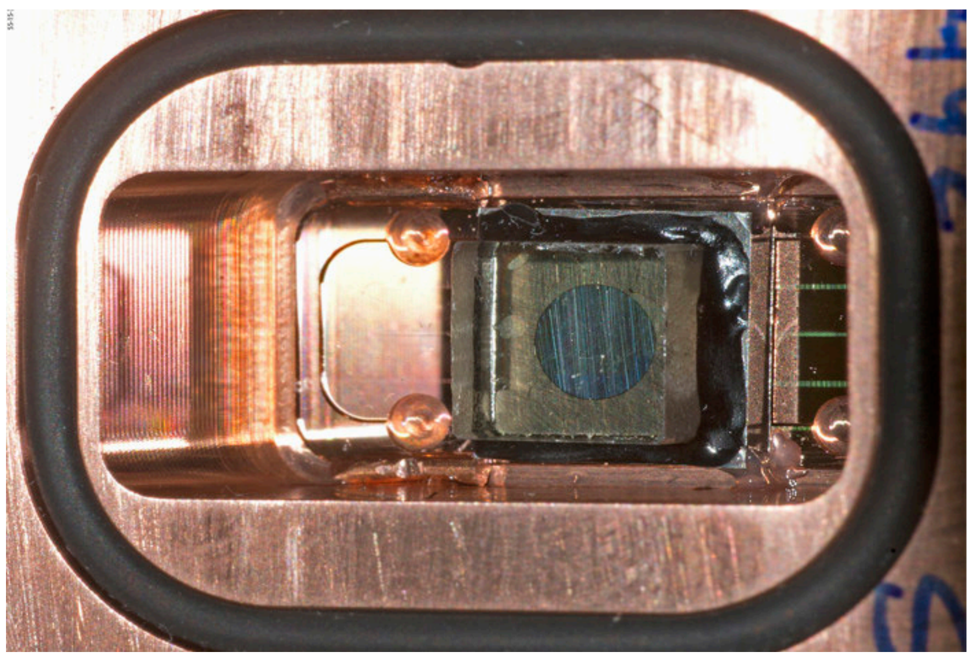
Los Alamos and Sandia collaborate on controlled measurements of plutonium at first-ever explored pressure, temperature, and density regimes

Los Alamos and Sandia national laboratories recently conducted plutonium experiments using Sandia's pulsed power Z Machine that reached regions of pressure, temperature, and density regimes—relevant to those seen during a nuclear weapons detonation—never before explored in the laboratory.

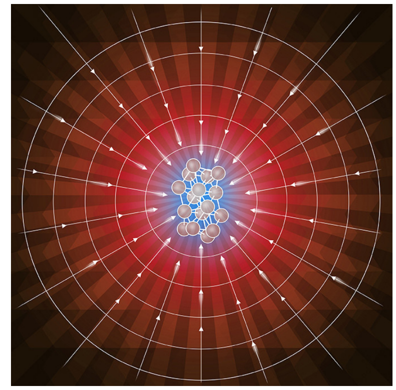
The Z Machine induces "shockless" magnetic compression that allows researchers to put plutonium into conditions not available with any other driver. These experiments both improve the fundamental understanding of how plutonium behaves in a dynamic environment and how that performance might change with age, sometimes looking at new material and comparing it against older material from the stockpile. A more complete phase diagram is important to nuclear weapons designers who need to understand if a nuclear weapon will perform as designed and how it will be affected by aging.

With disks or squares of mirror-finished plutonium—8 to 12 millimeters in diameter and 1/10 to 1/2 of a millimeter thick—scientists and engineers from Los Alamos and Sandia directed immense electrical energy onto the target with the Z Machine. This hugely energetic, pulsed-power device creates a uniform, very fast magnetic pressure wave that compresses the plutonium sample, causing its phase to change, essentially reordering its atomic structure. Plutonium is a complex material possessing multiple solid phases and a liquid phase. Scientists are trying to understand where these phase transitions occur in dynamic settings to develop a phase diagram that describes where the phase boundaries are in terms of pressure, temperature, and density.

Los Alamos's role in these experiments includes producing the plutonium samples (target assemblies), fabricated by Nuclear Materials Science (MST-16) in collaboration with scientists from Materials Science and Technology (MST) Division, Explosive Science and Shock Physics (M) Division, and Sandia National Laboratories.



Plutonium alpha-phase metal samples are sandwiched between platinum sample holders and transparent lithium-fluorite windows and mounted in Z target copper panels. The target assemblies are made at Los Alamos National Laboratory.



The Z Machine was used to study plutonium under extreme pressures and temperatures.

These experiments support the Stockpile Stewardship program—to ensure the safety, security, and effectiveness of the U.S. nuclear deterrent without the need for full-scale nuclear testing—and the extreme environments subcategory of the Materials for the Future science pillar. Funding for the Los Alamos effort is supported through Science Campaign 2 (Dana Dattelbaum, program manager).

Technical contact: Russell Olson (Neutron Science and Technology, P-23) (Science Campaign 2 Project Leader)

Cybersecurity cont.

through the Laboratory Directed Research and Development program, with later funding by the Defense Advanced Research Projects Activity (DARPA) for the applied demonstration work for our quantum encryption technology. The Department of Homeland Security's Transition to Practice program within the department's science and technology directorate helped bring the technology to market. For more coverage of the technology at RSA, see www.darkreading.com/endpoint/truly-random-number-generator-promises-stronger-encryption-across-all-devices-cloud/d/d-id/1324566.

Technical contact: Ray Newell

Subatomic physics researchers successfully polarize protons to be used in studying sea quark dynamics

Members of the Subatomic Physics group (P-25), in collaboration with the University of Virginia (UVa), have developed a novel polarized target system that is aimed at determining a possible contribution of sea angular momentum to the nucleon spin. Past experimental measurements have shown that about half of the spin of the proton comes from the spin of its quarks and gluons. Recent theoretical and experimental efforts focus on how the orbital angular momentum (OAM) of the quarks and gluons contribute to the proton's spin. These efforts show that the OAM contribution of the sea quarks could be large. The upcoming E1039 experiment at Fermilab National Accelerator Laboratory will access the sea quark Sivers function by measuring Drell-Yan pairs produced using a 120-GeV unpolarized proton beam directed on a transversely polarized target. A non-zero Sivers function would indicate a contribution of the sea quark OAM to the spin of the proton.

Scientists in P-25, collaborating closely with the polarized target team at UVa, are responsible for developing and testing the E1039 polarized target system. P-25 scientists are developing a new polarization measurement technique.

Polarizing protons for use in studying these nuclear effects is an established, but challenging procedure. Proton samples need a high magnetic field of 5 T and low temperature (~1 K) to reach a polarization of only 0.5%. By using a process called dynamic nuclear polarization (DNP), protons in a paramagnetic material can reach higher polarization by bombarding them with microwave RF at $\upsilon_e \pm \upsilon_p = 140.4 \pm 0.3$ GHz for up/down polarization. For example, protons in the hydrogen atoms of irradiated ammonia (NH_3) can reach polarization levels of >90%. The polarization of protons is measured via a nuclear magnetic resonance (NMR) technique. In NMR, an RF signal at the Larmor frequency of the proton is sent through an RLC circuit where a coil is embedded in the target material. As the number of protons in a particular state increases, the voltage across the circuit increases/decreases for absorption/emission of RF, indicating a net spin up/down polarization of the protons.

Andi Klein and David Kleinjan (P-25) and the UVa group successfully measured a proton polarization of 90% at the UVa polarization lab in April. The polarized target system, provided by Los Alamos is composed of a 5 T superconducting magnet and a refrigerator that provides cooled liquid helium at 1 K to the target chamber located in the 5 T field (Figure 1). The polarized target system was first brought to 5 T and 1 K. Then the irradiated NH_3 material was put in this high magnetic field, low temperature environment.

The NMR system developed at Los Alamos by Pat McGaughey and Jacqueline Mirabal-Martinez (P-25) successfully measured the thermal equilibrium polarization, which is needed as a baseline. DNP was achieved with microwave RF, and the NMR system successfully measured real time polarization increase, up to 90% (Figure 2). The established UVa Liverpool Q-meter NMR system ran in parallel and showed good agreement with the new Los Alamos NMR system. With a working polarized target in hand the E1039 installation will start in the near future and the data taken will be crucial in understanding the origin of the proton spin. This fundamental science project supports the Lab's core missions and the Nuclear and Particle Futures and Science of Signatures science pillars by developing experimental techniques relevant to applied scientific work and expertise and capabilities in particle detection and data acquisition and data analysis. Los Alamos's Laboratory Directed Research and Development program supports the Los Alamos portion of the work.

Technical contacts: Andi Klein, David Kleinjan

Below: Illustration depicting the origin of the nucleon spin, which remains a mystery.

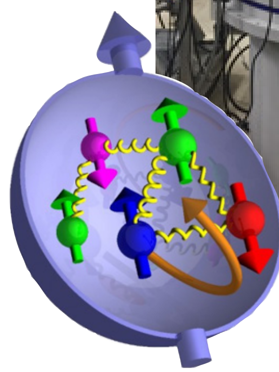


Figure 1: The working polarized proton target system. The circular plate at the bottom is where the beam will enter.

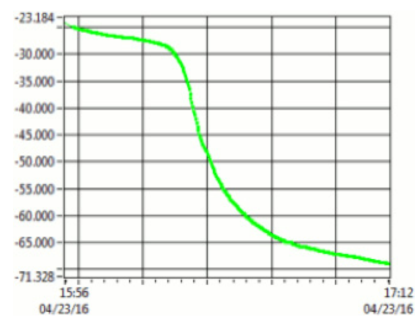


Figure 2: Live time polarization of the protons in the irradiated NH_3. The *y*-axis is arbitrary units, the bottom right points correspond to ~90% polarization.

SPIDER scales up to measure plutonium fission product yields

Accurate nuclear data is central to the development of robust theoretical fission models, which guide advances in nuclear weapons and nuclear energy technologies. At the Los Alamos Neutron Science Center (LANSCE), SPIDER, the spectrometer for ion determination in fission research, has been designed, assembled, and commissioned to measure fission product yields. The main goal is to reduce uncertainties in the energy-dependence of fission product yields.

Following engineering studies at LANSCE, conducted October through December, 2015, the design of a scaled-up SPIDER instrument capable of achieving target accuracy for plutonium is being finalized.

SPIDER provides unambiguous identification of fission product mass by using ultra-fast micro-channel plate (MCP) detectors and axial ionization chambers to register the velocity and kinetic energy, respectively, of coincident fission products. Data on the total kinetic energy release and prompt neutron emission per fission event are acquired simultaneously.

The time-of-flight section for one side of SPIDER is shown in Figure 1, with some components suppressed for clarity. As fission products pass through a thin carbon film, secondary electrons are emitted and guided onto the MCP detector via electrostatic deflectors. The MCP is an electron multiplier and the collected charge marks the instant the particle passes the MCP. The difference between the stop and start MCP signals is a measure of the time it takes to traverse the distance separating the detectors or a measure of velocity.

Due to the large-area (7.5-cm diameter) of each MCP, some deviation from the nominal MCP separation distance is expected. A set of position-sensitive delay-line anode (DLA) detectors is positioned beneath each MCP to measure the effective flight path distance. The DLAs consist of two bare copper wires wound orthogonally to produce *x* and *y* position coordinates that map the area of the ^{nat}C foil. In early measurements, the majority of position hits from fission events passing the time-of-flight system were improperly identified and, thus, the resulting information was inadequate to reconstruct the true fission product velocity.

An improved read-out scheme for the DLA assemblies was implemented during the 2015 run cycle at the Lujan Center, with the relevant position data for the fission events from ^{239}Pu shown in Figure 2. The image of the position hits in the start detector resembles the shape of the target, while that in the stop detector resembles the shape of the stop foil. The halo surrounding the position hits in both histograms arises from low-level electronic noise, known as dark current, within the MCP detectors. Measured deviations from the nominal flight path length of 67.5 centimeters are seen in the middle histogram. The new read-out scheme leads to a good reconstruction of the true fission product velocity and an optimized performance of the time-of-flight section of the spectrometer.

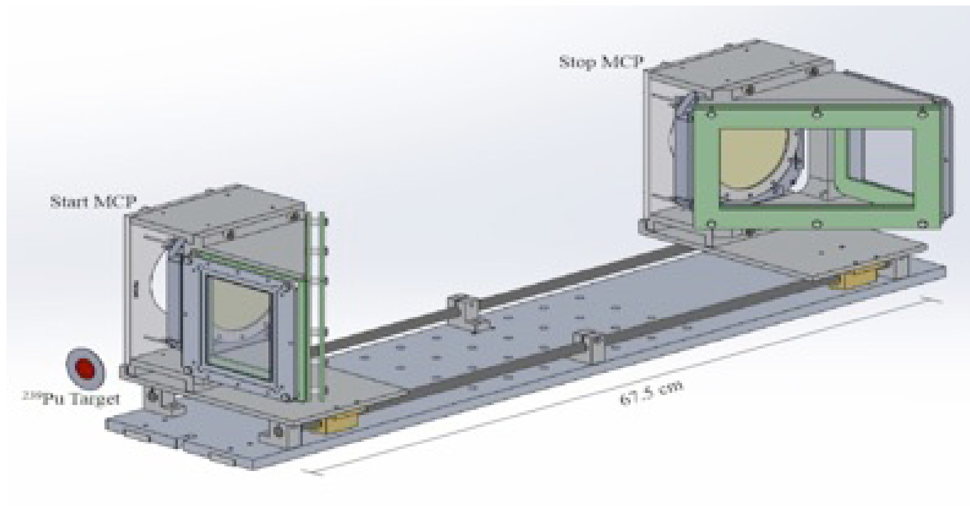


Figure 1: Time-of-flight assembly for one side of the SPIDER spectrometer. Each sub-assembly consists of an MCP detector, delay-line anode housed below the MCP, and a set of electrostatic mirrors above the MCP detectors. As shown, a particle would traverse the system from left to right.

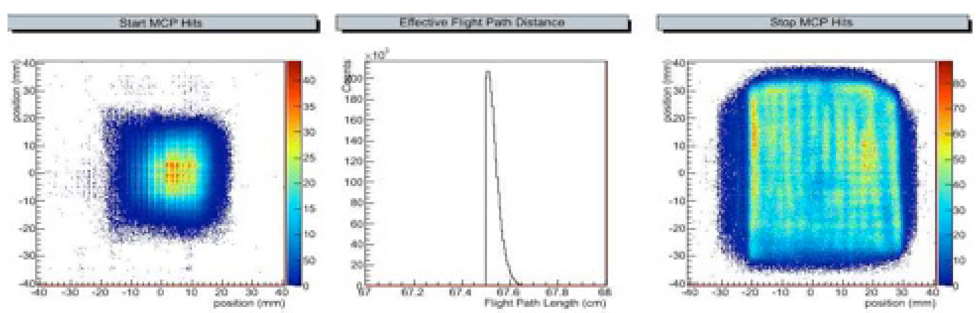


Figure 2: Left: Position hits registered in the start MCP. Middle: Effective flight path length of fission products registered by the time-of-flight assembly. Right: Position hits registered in the stop MCP.

The improved performance of the position readouts from the DLAs moves SPIDER closer to achieving a 1% mass resolution in fission product yield measurements.

The reliable performance of the DLAs is a requisite for the upgrade of the SPIDER spectrometer to a multi-arm device

continued on next page

SPIDER cont.

Figure 3: A conceptual drawing for the higher efficiency SPIDER spectrometer upgrade.

shown in Figure 3. This spectrometer is under development for the study of fission product properties from events induced by fast neutrons, a neutron energy region accessible at the Weapons Neutron Research facility. An order-of-magnitude gain in detection efficiency is anticipated for the larger SPIDER array, making it feasible to measure reactions with reduced fission cross sections. The cylindrical chamber design includes 20 MCP-DLA assemblies, 16 axial ionization chambers, and measures slightly over 152 centimeters in diameter.

This new instrument will usher in the means to measure properties of a fissioning system across a wide excitation energy range and will be well- positioned to collect valuable nuclear data for constraining fission models. While SPIDER's current mission is to measure fission product yields from plutonium, there are other potential uses for the instrument. One proposal is related to neutrinos produced in nuclear reactors. The discrepancy between the calculated production of neutrinos in reactors and what is experimentally observed is roughly 5 percent, which could be due to fission product yield errors used in calculations.

Laboratory Directed Research and Development funded the construction of the original SPIDER instrument in support of the Laboratory's Nuclear and Particle Physics Pillar for application to basic studies of nuclear fission. NNSA Science Campaign 1 funded the spectrometer upgrade and the current plutonium measurement program. The work supports the Lab's Stockpile Stewardship and Energy Security mission areas and the Nuclear and Particle Futures science pillar.

References: "The SPIDER fission fragment spectrometer for fission product yield measurements," *Nucl. Inst. Meth. A* 788, **59** (2015). Authors: Krista Meierbachtol (Advanced Nuclear Technology, NEN-2); Fredrik Tovesson, Dan Shields, Matthew Devlin, John O'Donnell (LANSCE Weapons Physics, P-27); Charles Arnold (Systems Design and Analysis, NEN-5); Todd Bredeweg (Nuclear and Radiochemistry, C-NR); Justin Jorgenson (Applied Engineering Technology, AET-5); Alexander Laptev (Pu Facilities, SB-PF); Arnie Sierk (Nuclear and Particle Physics, Astrophysics & Cosmology, T-2); Morgan White (X Computational Physics, XCP-5); with collaborators from University of New Mexico and Colorado School of Mines.

Arnold, C.W. *et al., Nucl. Inst. Meth*. A 764, **53** (2014).

Technical contact: Fredrik Tovesson

Experimental results from a laser-driven neutron source for MaRIE, research, and global security

At Los Alamos National Laboratory, researchers have recently pioneered a novel short duration yet extremely intense neutron source using short-pulse laser. At the Trident Laser Facility, one of the most intense and powerful short-pulse lasers in the world, a laser beam can be concentrated to peak intensity up to 10^{21} W/cm^2.

The beam, interacting with an ultrathin (sub-micron) deuterated plastic CD (or CD_2) foil target, drives a high-energy deuteron beam, which produces neutrons in a beryllium converter. This neutron source features high intensity and directionality, ~10^{10} fast neutrons per steradian per shot with extremely short neutron pulse duration i.e., a few nanoseconds.

The source has already been used to demonstrate global security applications, i.e., in the development of a new generation of detectors for active interrogation of potential clandestine nuclear material.

This recent work demonstrates a bright moderated neutron source, which will enable a new generation of nuclear physics experiments and applications, such as nuclear resonance transmission analysis for isotopic assay of irradiated nuclear fuel and bulk-temperature measurements in shock–driven material experiments as needed for MaRIE, neutron diffraction diagnostics, neutron therapy. etc. MaRIE is the Laboratory's proposed experimental facility for studying Matter-Radiation Interactions in Extremes.

During an experimental campaign in February/March 2016, the energy spectral components of the source were fully characterized in each pulse by a set of neutron time-of-flight detectors. The results showed the fast neutron component coming from the initial neutron production, as well as the epithermal, thermal, and cold (few meV) components after the moderation of the neutrons. For the first time, the researchers obtained evidence of the detection of a neutron

continued on next page

Laser-driven cont.

resonance in a laser-driven neutron experiment. The results show the path toward neutron resonance spectroscopy as a diagnostic for MaRIE and the first direct comparison of a laser-driven neutron source with a spallation source such as the Los Alamos Neutron Science Center.

The experiment involved strong collaborations among Nuclear Engineering and Nonproliferation, Physics, and Materials Science and Technology divisions as well as Darmstadt University (Germany) and UC Berkeley. The activity was supported by Los Alamos's Laboratory Directed Research Development Program. The activity was led by A. Favalli (Safeguards Science and Technology, NEN-1) and S. Vogel (Materials Science in Radiation and Dynamics Extremes, MST-8).

Technical contact: Andrea Favalli

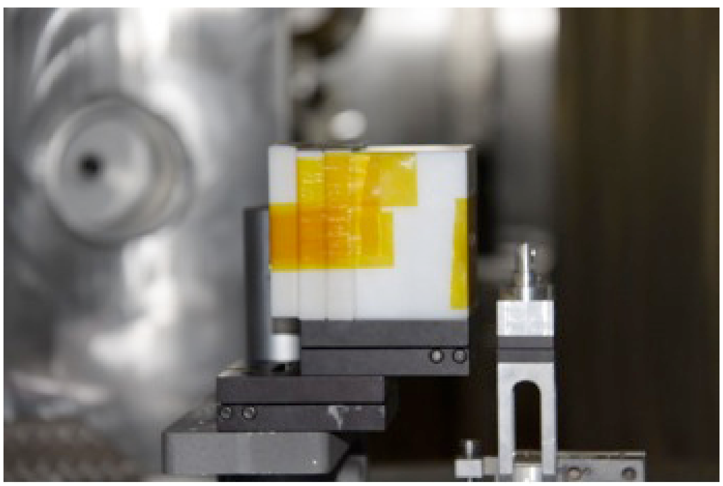


Photo shows the high-density polyethylene moderator block (white), with the embedded beryllium ion-to-neutron converter, and the target holder. The thickness of the moderator was optimized experimentally by adding layers of polyethylene and monitoring the thermal neutron production.

Celebrating service

Congratulations to the following Physics Division employees celebrating service anniversaries recently:

Mark Peters, P-21	35 years
Tsutomu Shimada, P-24	30 years
Steve Batha, P-DO	20 years
Melvin Borrego, P-27	15 years
Anna Llobet, P-23	15 years
Richard Van De Water, P-25	15 years
Joseph Cowan, P-24	10 years
Daniel Shields, P-27	5 years
Sky Sjue, P-21	5 years
Carl Wilde, P-23	5 years

HeadsUP!

May is Motorcycle Safety Awareness Month

Governor Susana Martinez proclaimed May as Motorcycle Safety Awareness Month in New Mexico. Richard Sturgeon (Compliance Programs, EPC-CP), chair of the Laboratory's Motorcycle Safety Committee, was the impetus behind the proclamation.

Sturgeon wrote to the governor suggesting that the state raise the safety awareness of New Mexican drivers and motorcyclists as the season for motorcycle riding begins. A few days after sending his initial letter, Sturgeon said, the Governor’s Office called him requesting language specific to New Mexico.

“I simply offered the state the same safety awareness mindset that we at LANL demonstrate on a daily basis," said Sturgeon. "It was a great honor to write a motorcycle safety awareness proclamation for our great state."

“Even though a number of motorcyclists in Los Alamos like myself ride year round, raising everyone’s safety awareness in May just makes sense,” said Sturgeon. He added that New Mexico drivers will begin to notice an increase in the number of motorcycles on the roads as the summer months approach. Sturgeon said Los Alamos's Motorcycle Safety Committee is asking everyone to look twice and share the road. "You just might be saving the life of a coworker, a friend or neighbor," he said.

PhysicsFlash

Published by the Experimental Physical Sciences Directorate.

To submit news items or for more information, contact Karen Kippen, ADEPS Communications, at 505-606-1822, or kkippen@lanl.gov.

For past issues, see www.lanl.gov/org/padste/adeps/physics/physics-flash-archive.php

Los Alamos NATIONAL LABORATORY EST. 1943

LA-UR-16-23694

Title:	Physics Flash May 2016
Author(s):	Kippen, Karen Elizabeth
Intended for:	Newsletter Web
Issued:	2016-05-25